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HEAT TRANSFER ENHANCEMENT IN MOTOR-BIKE SILENCER USING DELTA WING VORTEX GENERATOR

PRITEE PUROHIT[1] & R B GURAV[2]

[1]*Assistant Professor, Department of Mechanical Engineering, Army Institute of Technology Pune, Maharashtra, India*

[2]*Reserach Scholar, Department of Mechanical Engineering, Army Institute of Technology Pune, Maharashtra, India*

ABSTRACT

A silencer is the passage through which exhaust gases leaves the vehicle after being combusted in the engine. The combustion temperature may reach close to 800ºC. Even though engines are provided with fins to keep it cool with air flow, the exhaust gases are forced out of the chamber while they are still hot. Thus, the silencer also gets heated by the effect of these gases. Hence, there is a need to reduce the effects of harmful heated exhaust gases. Therefore, manufacturers provide chambers within stock silencers to curb sound and emission. The exhaust gases bounce off these chambers and thus tend to keep the silencer hot. Extreme heat can cause a host of problems and results in the reduction of engine performance. Also, excess heat generation may results in deterioration of motor oil properties and it can create deposits on the surface of intake valves. Deposits on the air valve affect the airflow inside the engine and it is the major reason of poor sealing of the entire combustion chamber. This series of events lead to misfire, rough idle and also reduced power and fuel economy. The hot spots on the silencer surface are reducing its life. The objective of this research is to increase convective heat transfer coefficient of air in the annular area of silencer and its enclosure sheet to enhance heat transfer using passive methods. Method employed to achieve these using delta wings as vortex generators on the enclosure sheet of silencer. We studied the flow behavior and convection heat transfer characteristics of fluid passing through an annular region between silencer outer surface and an enclosed sheet. The enclosed sheet is installed with delta wing attached on the surface facing silencer at an angle of attack, α=45º and aspect ratio, Λ=2.0. The use of delta wing increases convective heat transfer coefficient and increases over all turbulence thus improves heat dissipation through the spaced annular region. Heat transfer and flow pattern are obtained at varying velocities at an angle of attack, α= 45º.

KEYWORDS: Heat Transfer, Convention, Silencer Cooling, Delta Wing & Heat Dissipation

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1. INTRODUCTION

The hot gases generated from combustion of fuel passes through the exhaust system of an automobile. A silencer is the passage through which exhaust gases leaves the vehicle after being combusted in the engine. The combustion temperature may reach close to 800°C. Even though engines are provided with fins to cool with the air flow, the exhaust gases are forced out of the chamber while they are still hot. Thus, the silencer also gets heated by the effect of these gases. The average operating temperature of most of bike silencer is around 130°C. An unavoidable side effect of silencer is back pressures due to this waste heat builds up on the silencer surface. If this waste heat cannot escape, it can overload the cooling system and can cause hotspots on the silencer surface.

Heat transfer augmentation or heat transfer intensification is the technique used for improving the heat transfer performance [1]. Improvement in performance of heat transfer aspect deals with improvements in factors like heat transfer coefficient h, pressure drop reduction and enhancement in the Nu number [2]. Vortex generator is

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the emerging and wide spread technique in the heat transfer enhancement [3]. Vortex generators generating the secondary flow fields and enhancing the heat transfer rate [4]. It has been also studied that there is always an interactions happening between the boundary layer and the vortex formed due to vortex generators. The vortices with high circulation which are located near the edges of boundary layer are reducing the boundary layer. It has been suggested in a study that to maintain the vortices near the boundary layer, the vortices should be originated from the inflow arrangements [5]. The inserts in the form of delta wings showed enhancement in the Nu number values approximately 5 to 15 times compared to the smooth tubes [6]. Vortex generators are the inserts having in triangular or rectangular shape which can either be punched or attached in the forms of small pieces to the fiat plate and it forms an angle of attack with the direction of main flow [7]. The inserts like delta wing are contributing the enhancement of the heat transfer rate through the generation of turbulent flow. The Nusselt number values are enhanced almost by 150-500% through delta wing vortex generators [8].

Vortex generator (VGs) are the protrusions from the heat transfer surfaces responsible for generating swirl of flow around an axis and leads to generation of vortices in the flow. These vortex generators play a crucial role in enhancement of heat transfer rate and pressure drop reduction. As these exhaust form passage for the hot gases and released to the atmosphere, they are also subjected to high temperature. An unavoidable side effect of silencer is back pressure and anything that backs up the exhaust pressure into the engine also increases the heat. If this waste heat cannot escape, it can affect the cooling rate of the system and results in the hotter engine running condition more than the normal temperature. It happens frequently at high speeds and causes hotspots on the silencer surface which in turn reduces the life of silencer. The objective is i) To find out heat transfer enhancement rate with delta wing vortex generator.

ii) To check heat transfer enhancement rate for various arrangements of delta wing vortex generator. Iii) To develop an enclosure sheet over the silencer surface which can reduce the silencer surface temperature than the conventional enclosure sheet using the passive methods. From literature survey, we found longitudinal vortices are far more superior to the transverse vortices to increase the heat transfer coefficient of fluid in the annular area of the silencer surface and the enclosure sheet. We used delta wings as vortex generator with the angle of attack, $\alpha=45°$ and the aspect ratio, $\Lambda=2.0$ as at varying inlet air flow velocities in the annular region between the silencer outer surface and the enclosure sheet. The benefit of this model is reduction in the silencer surface temperature without any external power source.

2. EXPERIMENTAL METHODS

2.1 CAD Model

The Selection of silencer is totally based on the availability and the most common usage by mass. As a result, we have chosen the silencer of Hero Honda Splendor Plus as it is the most common bike used by everyone. Splendor was No. 1 selling motorcycles in October, 2016 with over 250,000 motorcycles. Its Exhaust Silencers are made of Stainless Steel, having cylindrical cross-section. Figure 1a shows the CAD model of sheet without delta wing, Figure 1b shows the CAD model of sheet with delta wing, Figure 1c shows theactual Enclosing Sheet and Figure 1d shows the aspect ratio dimensions.

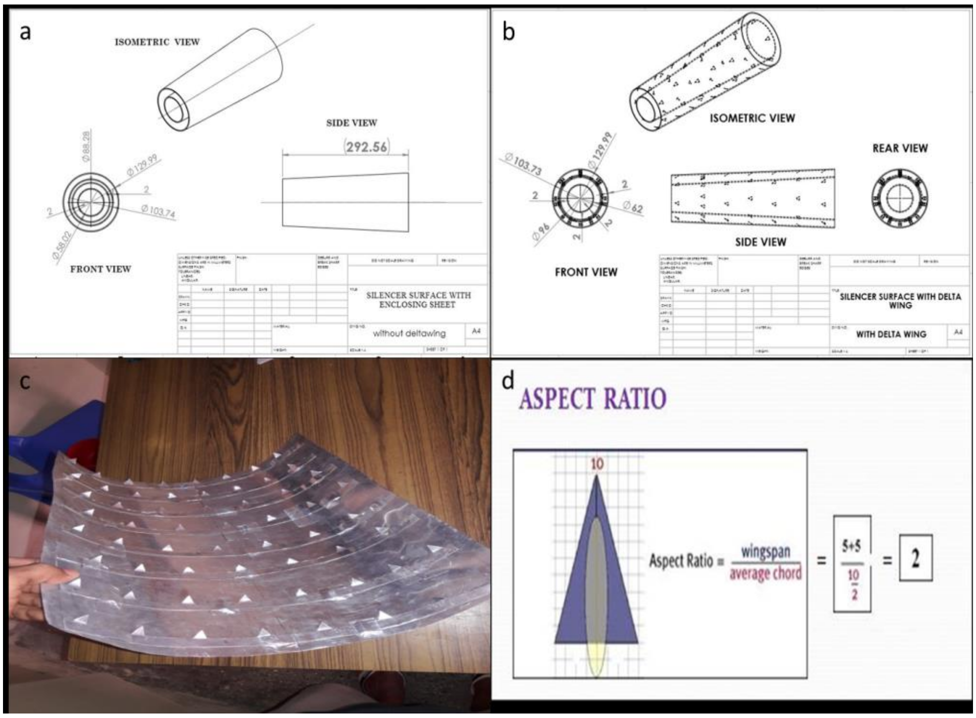

Figure 1: a) CAD Projections of Sheet without Delta Wing, b) CAD Projections of Sheet with Delta Wing, c) Actual Enclosing Sheet and d) Aspect Ratio Dimensions

2.2 CFD Analysis

CFD analysis is done using Ansys Fluent software. CFD analysis is done for three sets of velocities 16.66 m/s, 22.22 m/s and 27.78 m/s. For each velocity, the analysis is done for the sheet without delta wings, for delta wings at the end, for delta wings at three places and for delta wings at four places. Figure 2 shows the temperature contours obtained at velocity of 16.66 m/s. Figure 2a is temperature contour for a sheet without delta wings, 2b is temperature contour for a sheet with delta wings at the ends, 2c is temperature contour for a sheet with delta wings at three places and 2d is temperature contour for a sheet with delta wings at four places.

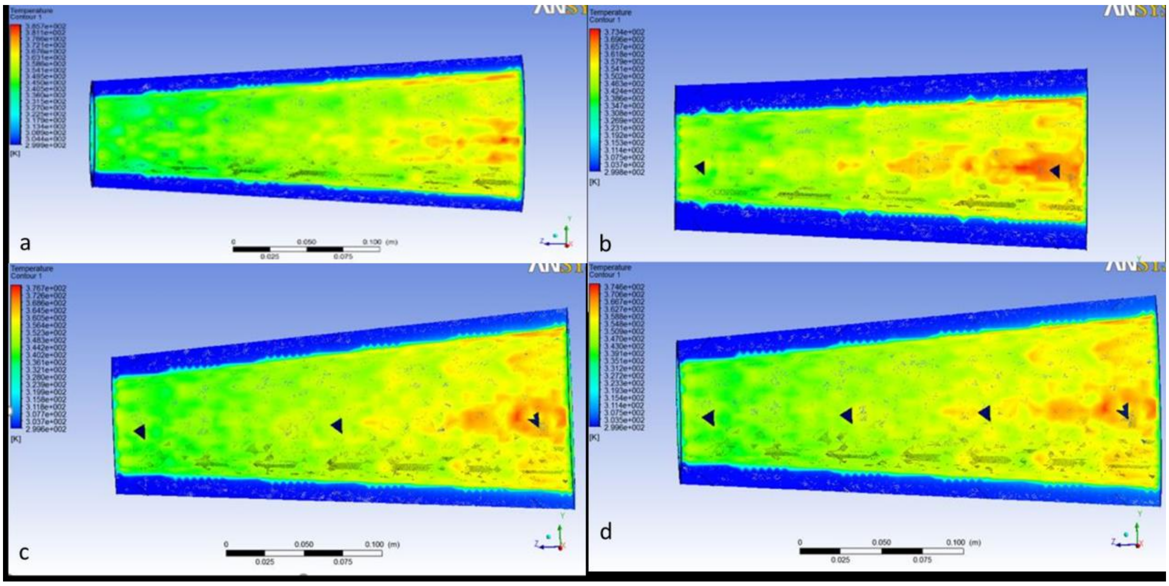

Figure 2: Temperature Contours Obtained at Velocity of 16.66 m/s.

Figure 3 shows the temperature contours obtained at velocity of 22.22 m/s. Figure 3a is temperature contour for a sheet without delta wings, 3b is temperature contour for a sheet with delta wings at the ends, 3c is temperature contour for a sheet with delta wings at three places and 3d is temperature contour for a sheet with delta wings at four places.

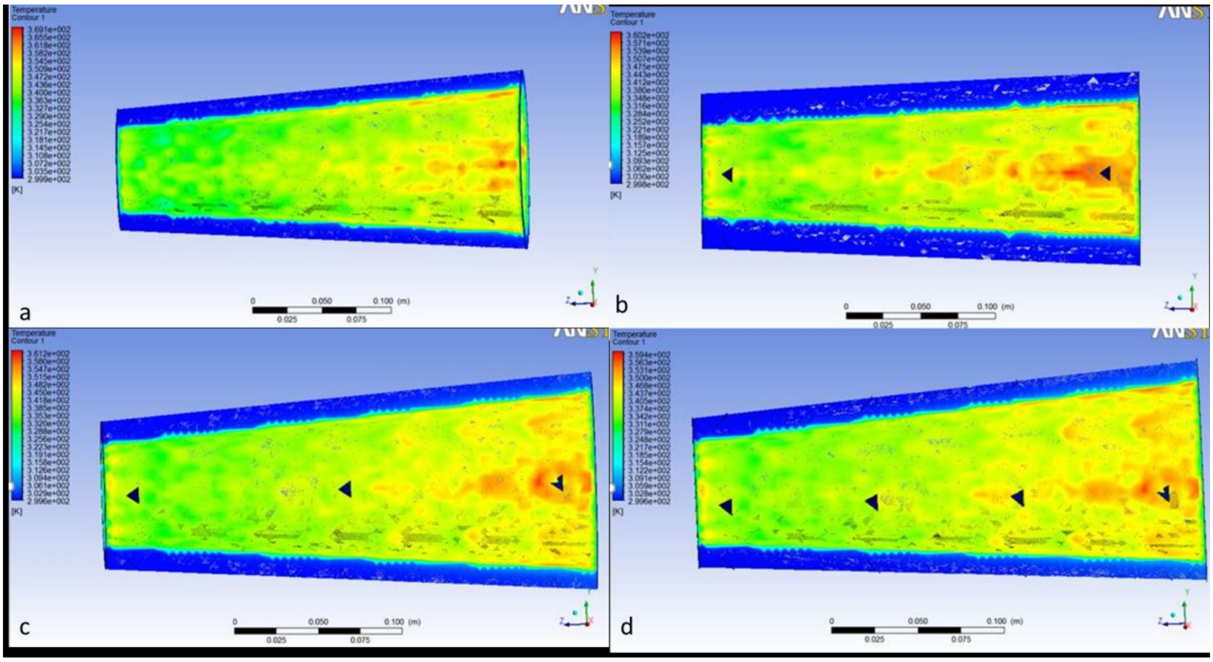

Figure 3: Temperature Contours Obtained at Velocity of 22.22 m/s.

Figure 4 shows the temperature contours obtained at velocity of 27.78 m/s. Figure 4a is temperature contour for a sheet without delta wings, 4b is temperature contour for a sheet with delta wings at the ends, 4c is temperature contour for a sheet with delta wings at three places and 4d is temperature contour for a sheet with delta wings at four places.

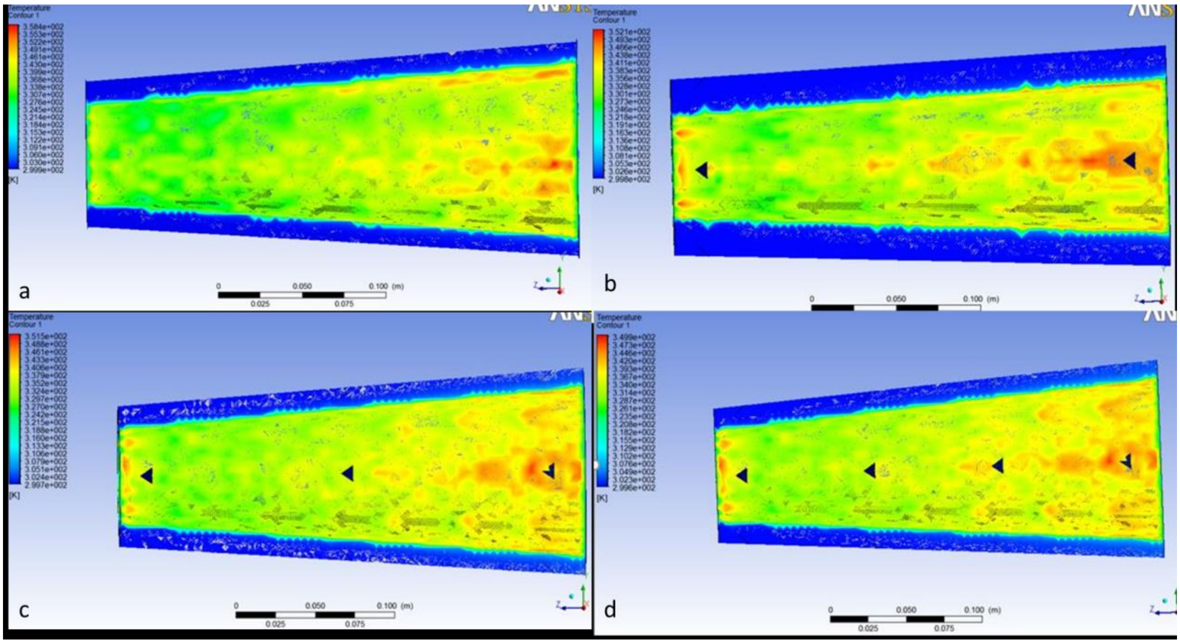

Figure 4: Temperature Contours Obtained at Velocity of 27.78 m/s.

2.3 Experimental Analysis

To study the effect of applying a shield over silencer with and without delta wings, the experimental study is also done. The present study was conducted using air as a working fluid to evaluate the effect of incorporation of delta wing vortex generator on a convective flow over a surface of motor bike silencer. Heat transfer analysis is done for aheat flux of 3502.23 W/m^2. The readings got after the steady state are used to calculate heat transfer coefficient h(W/m^2), Nusselt number Nu and Reynolds number Re. Detail calculation is summarized below.

2.3.1 Calculations

Surface Area, A_s

$$A_s = \pi \times [r \times (r + l) + R(R + l)]$$

Where,

R = Radius of silencer at outlet = $\frac{103.74}{2} = 51.87\text{mm}$

r = Radius of Silencer at inlet = $\frac{58.02}{2} = 29.01\text{mm}$

L = Length of Silencer = 292.56mm

$$L = \sqrt{h^2 + (R - r)^2} = \sqrt{292.56^2 + (51.87 - 29.01)^2} = 293.4517\text{mm}$$

$$\therefore A_s = \pi[(29.01) \times (29.01 + 293.45) + 51.87 \times (51.87 + 293.45)]$$

$$A_s = 85659.64861 \text{ mm}^2$$

Annular Area,

$$A_1 = \frac{\pi}{4} = [(129.99)^2 - (103.74)^2] = 4818.7417 \text{ mm}^2$$

$$A_2 = \frac{\pi}{4} = [(88.28)^2 - (58.02)^2] = 3476.9875 \text{mm}^2$$

$$A_{annular} = \frac{A_1 + A_2}{2} = \frac{4818.7417 + 3476.9875}{2} = 4147.864 \text{ mm}^2$$

For Constant Surface Heat Flux,

Typical values of h for forced convection for gases: 25 W/m^2 to 250 W/m^2.

$$Nu = \frac{hD_h}{k} = \frac{\text{Convection heat transfer}}{\text{Conduction heat transfer}}$$

$$Pr = \frac{\vartheta}{\alpha} = \frac{\text{Momentum diffusivity}}{\text{Thermal diffusivity}}$$

$$Re = \frac{\rho VD}{\mu} = \frac{\text{Inertia force}}{\text{Viscous force}}$$

Where,

Pr is Prandtl Number

Hydraulic Diameter,

$$D_2 - D_1 = 129.99 - 103.74 = 26.25\text{mm}$$

$$d_2 - d_1 = 88.28 - 58.02 = 30.26\text{mm}$$

$$(\text{Hydraulic Diameter})_{\text{Average}} = \frac{26.25 + 30.26}{2} = 28.255\text{mm}$$

3. RESULTS AND DISCUSSIONS

The value of Heat flux applied for all cases is 3502.23 W/m^2. The values of Nusselt number Nu, heat transfer coefficient h, and Reynolds's number Re is determined and tabulated in Table 1. The experimental data of Nusselt number Nu, Reynolds number Re and heat transfer coefficient h obtained is compared with the CFD results. From experimental result, it found that 16.67 m/s 152% enhancement in the Nu number obtained for a sheet with delta wings at four places. At velocity of 22.22 m/s 161% enhancement in the Nu number obtained for a sheet with delta wings at four places. At a Velocity of 27.78 m/s 111 % enhancement in the Nu number obtained for a sheet with delta wings at four places. Results are in well agreement with the results obtained by CFD analysis.

A vortex region can be observed in all figures which show the flow revolving around a longitudinal axis line. Vortex can be curved or straight. The delta wing has generated a lift which is achieved by the front part of vortices those are carried through longitudinal path through the main flow as shown in Figure 2-4. These vortices are responsible for fluid interchange near the boundary layer with the fluid flowing from the main stream. The bulk mixing that is thinning of the boundary layer is the predominant factor for the enhancement in the heat transfer rate using delta wing vortex generation.

Table 1: Effect of Delta Wings on Heat Transfer Rate

Case No	Number of Delta Wings	Velocity, V(m/s)	Silencer surface temperature, T_S (K)	Convection Heat Transfer coefficient, h(W/m^2)	Nusselt Number, Nu	Reynolds Number, Re
1	0	16.667	349.4039	50.9614	53.0316	27694.69
	8	16.667	348.8689	55.222	57.38	27617.63
	12	16.667	348.233	69.224	71.144	26963.449
	16	16.667	348.1255	79.42	81.5825	26932.312
2	0	22.22	340.5705	71.26	73.936	36686.88
	8	22.22	339.9691	90.8563	92.045	36521.0247
	12	22.22	339.3534	105.44	108.777	36247.586
	16	22.22	339.1621	116.037	119.881	36364.19
3	0	27.78	334.8657	157.0611	163.8393	45167.77
	8	27.78	333.9633	161.876	167.45	45586.554
	12	27.78	333.4940	163.01	168.907	45752.64
	16	27.78	333.4206	175.838	182.162	45730.22

The present study was conducted to evaluate the effect of Reynolds number and delta wing vortex generator on a convective flow over a surface of motor bike silencer. Finite volume method is used to study the effect of above parameters on motor bike silencer. The simulations were performed for Re (26000 to 46000) considering three different numbers of Delta wing vortex generator (4,8 and 16). At 16.667 m/s velocity; there is consistent decrease in the silencer surface temperature with an increase in number of delta wings on the enclosure sheet and temperature difference between the silencer surface temperature with no delta wings and 16 delta wings is 1.2784 K. Heat transfer coefficient, h increased by

28.4586 W/m^2 K.

4. CONCLUSIONS

- At 22.22 m/s velocity the difference between the silencer surface temperature with no delta wings and 16 delta wings is 1.4085 K. Heat transfer coefficient, h increased by 44.77 W/m^2.
- At 27.78 m/s velocity the difference between the silencer surface temperature with no delta wings and 16 delta wings is 1.4451 K. Heat transfer coefficient, h increased by 18.7769 W/m^2.
- At 16.667 m/s velocity, the difference between the silencer surface temperature with no delta wings and offset arrangement of 36 delta wings is 3.1518 K. Heat transfer coefficient, h increased by 30.2056 W/m^2 K.
- At 22.22 m/s velocity the difference between the silencer surface temperature with no delta wings and offset arrangement of 36 delta wings are 7.0865 K. Heat transfer coefficient, h increased by 84.2626 W/m^2 K.
- At 27.78 m/s velocity the difference between the silencer surface temperature with no delta wings and offset arrangement of 36 delta wings are 6.5958 K. Heat transfer coefficient, h increased by 76.8599 W/m^2 K.

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AUTHORS PROFILE

Dr Pritee Purohit, is currently working as Assistant Professor in the Department of Mechanical Engineering at Army Institute of Technology Pune. She has completed her Ph.D in 2017 from Government College of Engineering Pune, affiliated to SavitribaiPhule Pune University Pune. She has completed her UG in Mechanical Engineering and PG in (Mechanical **-** Heat Power) in 2004 and 2006 respectively. She has fifteen (15) years of teaching experience. Her fields of research are heat transfer, fluid dynamics, high temperature corrosion and thermal barrier coatings. She has twenty five (25) plus national and International conference and Journal Publications to her credit. She has one SCI publication out of seven (7) International Journal Publications. She has filed two (2) patents in the field of Mechanical Engineering.

Prof. Raviraj Bhairu Gurav, is a Ph.D. Scholar of MAEER's MIT Kothrud, Pune affiliated to SPPU, Pune and working as Assistant Professor in Mechanical Engineering at Army Institute of Technology, Pune affiliated to SPPU, Pune. He has done M.E. (Mechanical **-** Heat Power Engineering) and has 16 years of teaching experience. His areas of interest are Fluid Mechanics and Heat Transfer. He has published five (05) papers in International Journals. He has worked on research projects in thermal engineering and heat transfer area. He also filed two (02) patents in the area of heat transfer and mechatronics.